

# Demonstrating Starshades



*Webster Cash  
University of Colorado*

*Exopag 7  
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# Demonstration is Crucial

**WE WILL NEVER FLY A NEW EXOPLANET TECHNOLOGY**

**UNTIL**

**IT HAS BEEN DEMONSTRATED**

**WITH ACTUAL ASTRONOMICAL RESULTS**

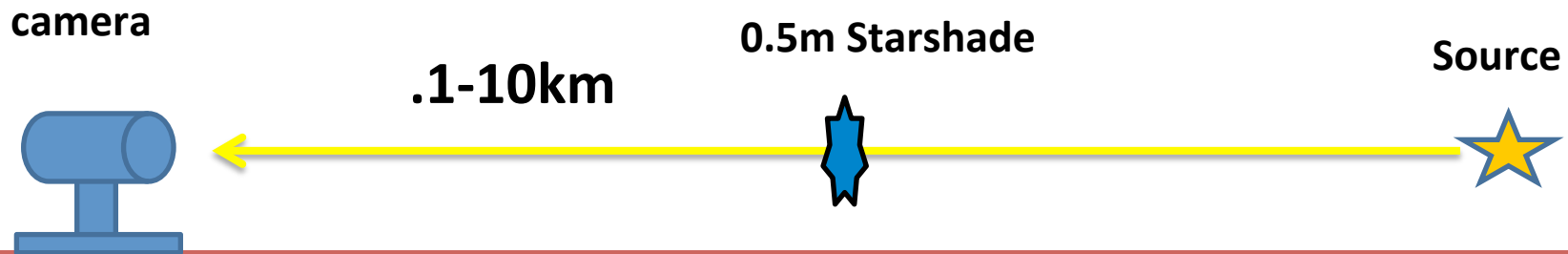
# DEMONSTRATION OF STARSHADES

STARSHADES WORK IN AIR

SAW THAT IN 2007 LAB TESTS  
UNDERSTOOD AND PUBLISHED 2011

ALLOWS BABY STEPS OF TECH DEV AT LOW COST

# Step 1: Ground Testing

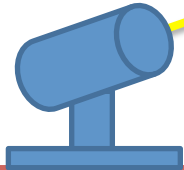
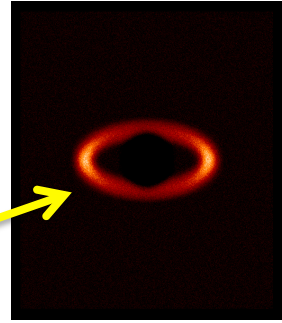


# Step 2: The Hilltop

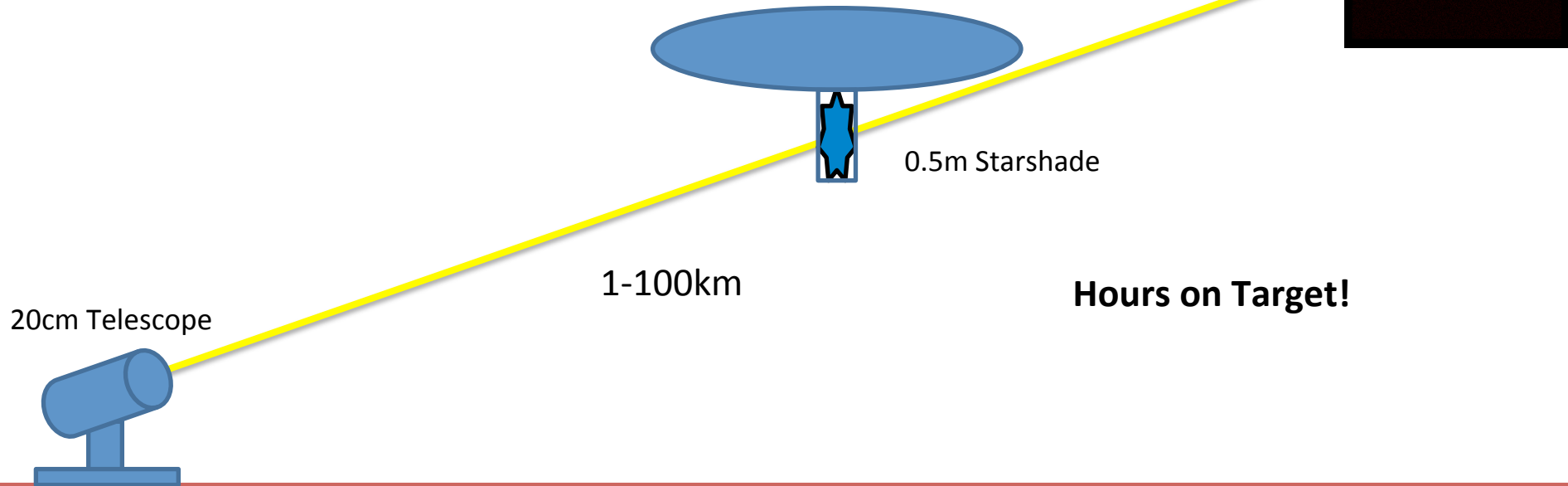
20cm Telescope

1-100km

0.5m Starshade



# Step 3: Telescope on Ground Starshade on Dirigible

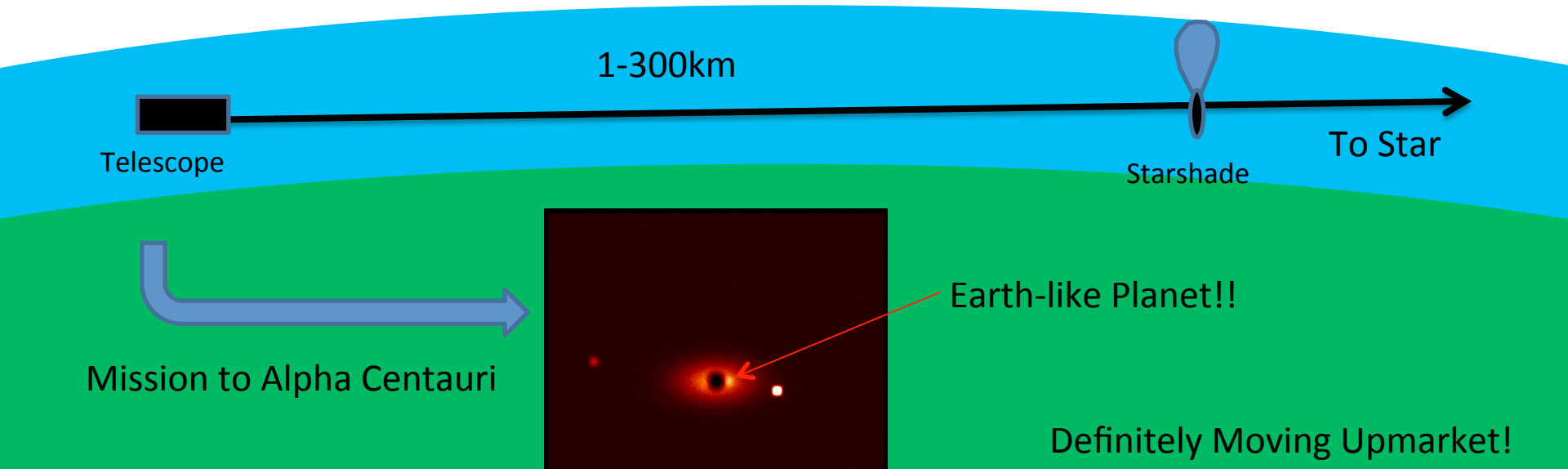


# Step 4: balloons and UAVs

Balloons allow greater separation  
and quieter atmosphere



Two Craft in Stratosphere  
One must have controlled flight



# Step 5: Low Cost Orbital Demonstration Mission

- OCT has a program of technology development missions
- Development and Demonstration of Exoplanet Technology top priority in NRC Technology Roadmap
- There is interest in such a mission very short term
- Relationship to SMD in flux because OCT is still new



# We Have Started Down that Road

- Funding from OCT and NASA Ames
- Team is Small and Lean
  - Colorado
  - Northrop
  - Ames
- Support for First Three Steps
  - Funding started in May
- Working on Transition to Step 4

# Step 1:

Basecamp Setup



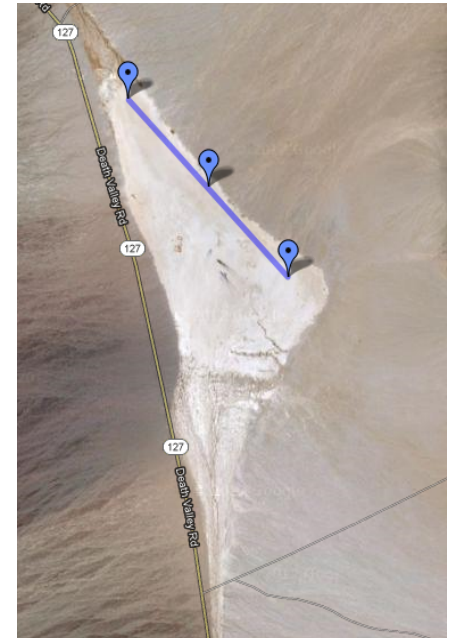
Telescope



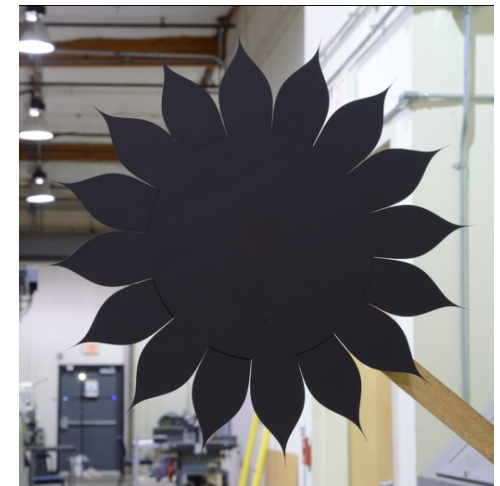
Starshade Support



Light Source

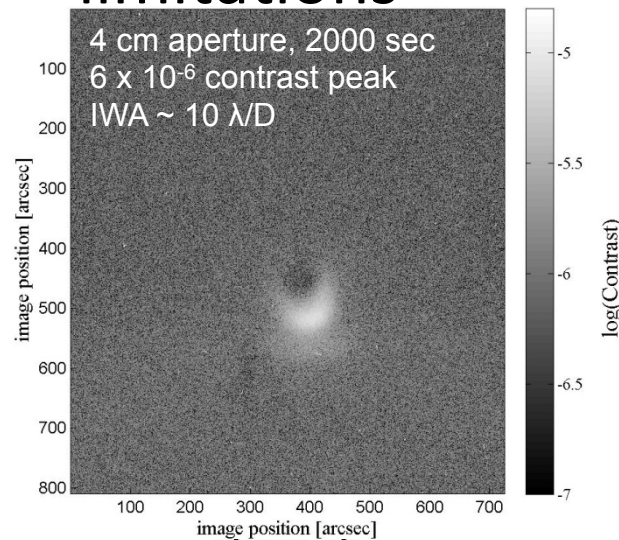
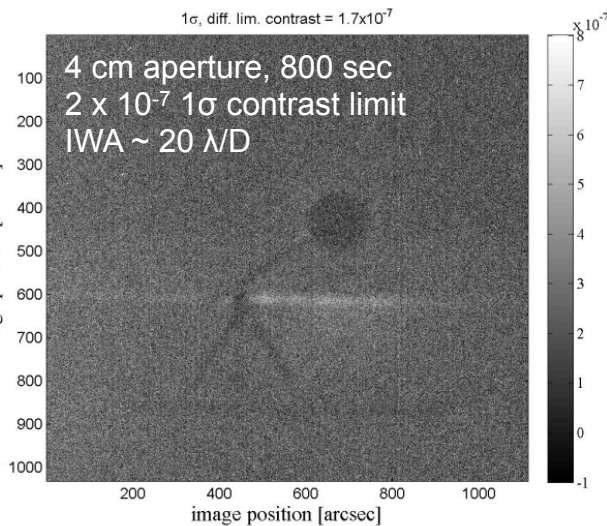


- Site: Dry Lakebed near Death Valley
- Setup nearly identical on 2 consecutive nights
- Separation: 1<sup>st</sup> night 1.5 km baseline, 2<sup>nd</sup> night 3 km baseline – both with starshade at  $\frac{1}{2}$  way point
- Telescope: Celestron 8"; added 4 cm aperture (off axis, no obscuration)
- Light source: Vollong 5W LED; ~6 feet above ground
- Starshade: fabricated in house to Cash (2006) shape prescription as well as possible
- Second night at longer range had significant wind conditions not present on first night

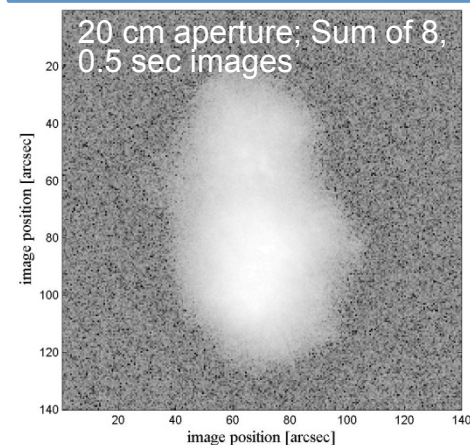


# Demonstrated better than $10^{-7}$ contrast, despite limitations

Small aperture, lower sensitivity

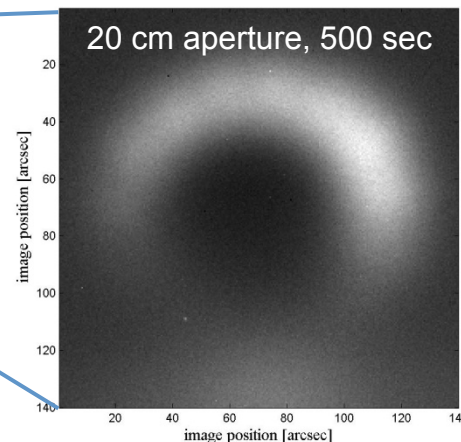
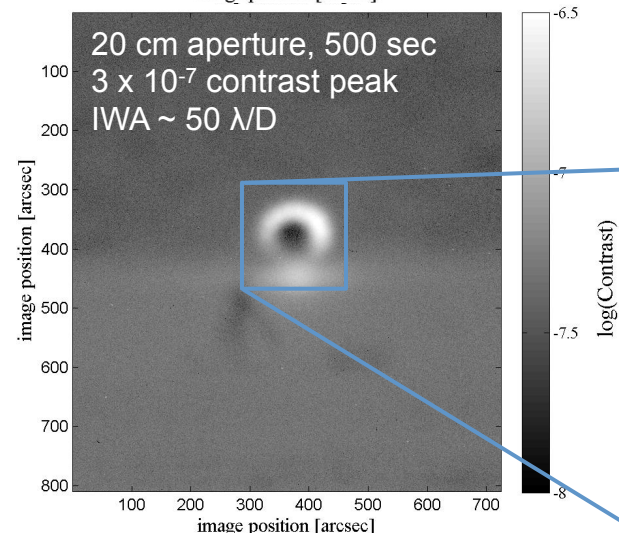
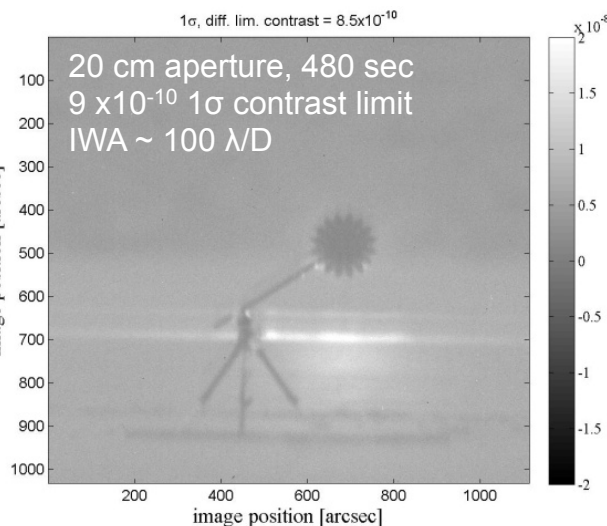


Atmospheric seeing could be limiting contrast performance at longer distance



Lamp at 3 km; no starshade

Large aperture, higher sensitivity



Starshade range = 0.75 km  
 ~20x design Fresnel #  
 Sensitivity & background limited

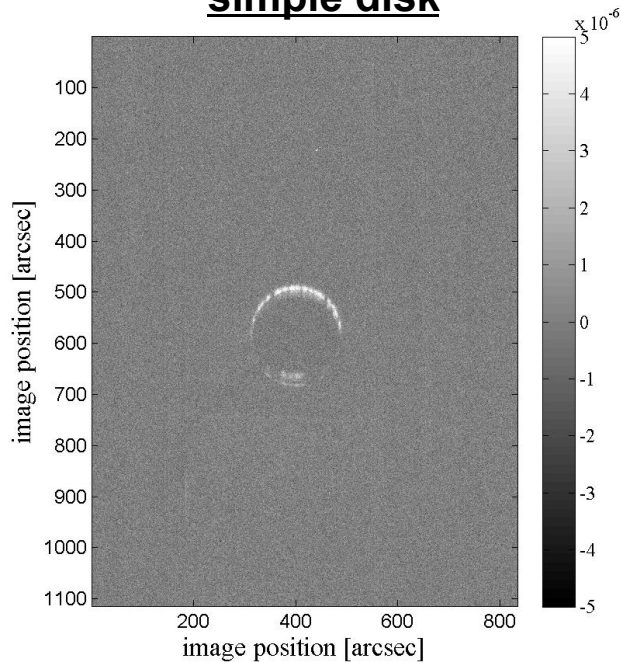
Starshade range = 1.5 km  
 ~10x design Fresnel #  
 Halo likely related to seeing

Starshade at 1.5 km



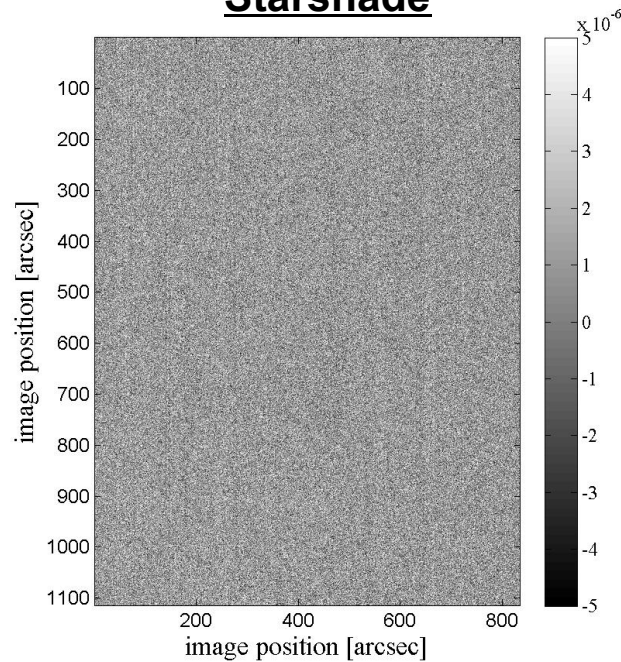
# Starshade Performs As Advertised!

Image with 60 cm  
simple disk



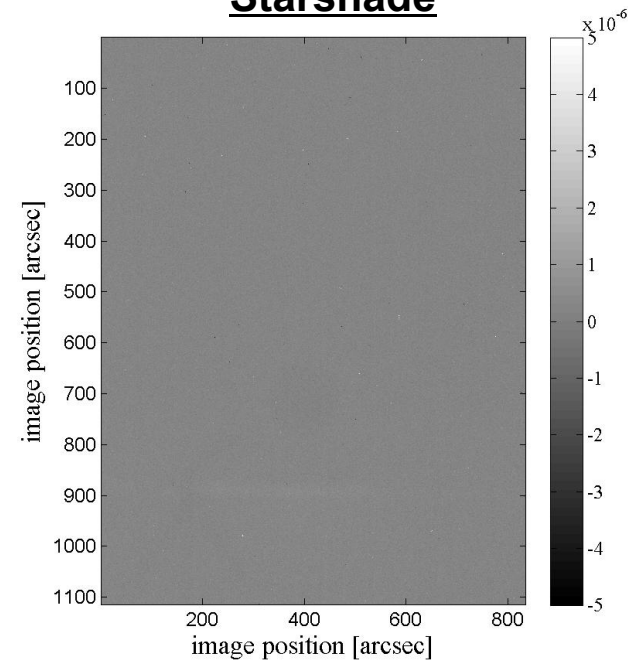
60 second exposure  
Peak Contrast  $\sim 5 \times 10^{-6}$

Image with 60 cm  
Starshade



60 second exposure  
 $1\sigma$  Contrast Limit  $\sim 2 \times 10^{-6}$

Image with 60 cm  
Starshade



800 second exposure  
 $1\sigma$  Contrast Limit  $\sim 2 \times 10^{-7}$

Short baseline (telescope to starshade = 0.75 km)

## Step 2

- Star going behind starshade and re-emerging
- Movie of this made yesterday morning.



# Step 3: Airship Ventures

- Airship Ventures
- Formation Flying Issues
- Built a Janus
  - Thanks, Charley!
- Went out of business unexpectedly in November
- Many options to continue
  - Leap to stratosphere now?



## Step 4: Stratospheric

**GOAL: Image the Alpha Cen system within three years**



*Detailed Studies Now*

*One option is Global Hawk plus High Altitude Balloon*

# Summary

- Goal:
  - Image the Alpha Centauri system in to the Habitable Zone in under 3 years
- Ground Tests Successful
  - Starshades work in the atmosphere!
  - Very high contrasts relatively easy to achieve
  - Starting hilltop work
- Addressing formation flying issues
  - Airship Ventures - gone
  - Currently assessing alternatives
    - Leap to Stratosphere now?
- Do large IWA, high contrast first
  - Evolve to smaller IWAs
- Design Low Cost Orbital Demonstrator
  - To be launched in under five years